CLAIMS (US way of presentation)

1/ A device for thermally insulating at least one undersea pipe, the device comprising:

· a thermally insulating covering surrounding said pipe(s);

· said covering itself being covered by an outer leakproof protective case, and said case being made of a flexible or semirigid material suitable for remaining in contact with the outside surface of said insulating covering when it deforms,

the device being characterized in that:

· said insulating covering comprises a phase-change material, preferably an insulating phase-change material confined in at least one container made of a flexible or semirigid material that is deformable; and

· said container(s) being disposed around said pipe(s).

2/ An insulating device according to claim 1, characterized in that in a cross-section of said pipe(s), level with said container(s), said pipe(s) is/are surrounded by said container(s) in substantially continuous manner.

3/ An insulating device according to claim 1, characterized in that said containers are placed close to the pipe in such a manner that said pipe does not come directly into contact with some of said container(s), and preferably does not come into contact with any of the containers.

4/ A device according to claim 3, characterized in that said containers are disposed against spacers, said spacers being disposed against and around said pipe in such a manner as to leave a gap between said containers and said pipe.

5/ A device according to claim 2, characterized in that said containers are spaced apart from said pipe by a distance of 5 mm to 10 cm, and preferably by a distance of 1 cm to 5 cm.

6/ An insulating device according to any preceding claim, characterized in that said pipe is surrounded by a second insulating material that is solid, being applied against said pipe, preferably in the form of a shell of syntactic foam, said container being pressed against said solid insulating material surrounding said pipe.

7/ A device according to claim 1, characterized in that said insulating covering covered in a said leakproof protective case comprises a main insulating material, preferably an insulating gel disposed between said outer case and said container(s) of phase-change material surrounding said pipe(s).

8/ An insulating device according to claim 7, characterized in that said main insulating material surrounds said pipe(s) and provides separation between said pipe(s) and said containers in the gap between said container(s) and said pipe(s).

9/ An insulating device according to claim 1, characterized in that in the portions of the pipe(s) surrounded by said containers, the device has at least two and preferably three or four containers in a said cross-section of said pipe(s) surrounded by said containers, and also preferably surrounding said pipe(s) in a manner that is substantially continuous.

10/ An insulating device according to claims 1, characterized in that said phase-change material presents a liquid/solid melting temperature that preferably lies in the range 20°C to 80°C, that is lower than the

temperature of the fluid flowing in said pipe when it is in operation, and higher than the temperature at which the fluid flowing inside the pipe present an increase in viscosity that is harmful for its ability to flow in said pipe.

11/ A device according to claim 10, characterized in that said insulating phase-change material comprises chemical compounds of the alkane family, preferably a paraffin having a hydrocarbon chain with at least 14 carbon atoms.

12/ A device according to the preceding claim, characterized in that said paraffin is heptacosane of formula $C_{17}H_{36}$ presenting a melting temperature of about 50°C.

13/ A device according to claim 1, characterized in that said main insulating material is constituted by an insulating mixture comprising a first compound consisting in a hydrocarbon compound such as paraffin or gas oil, mixed with a second compound consisting in a gelling compound and/or a structuring effect compound, in particular by means of cross-linking, such as a second compound of the polyurethane type, of the cross-linked polypropylene type, of the cross-linked polyethylene type, or of the silicone type, and preferably said first compound is in the form of particles or microcapsules dispersed within a matrix of said second compound.

14/ A device according to claim 13, characterized in that said first compound is selected from alkanes such as paraffins, waxes, bitumens, tars, fatty alcohols, and glycols, said first compound preferably being a phase-change compound.

15/ A device for thermally insulating at least one undersea pipe, the device being characterized in that it

includes at least two leaktight transverse partitions, each of said partitions being constituted by a closed rigid structure having said pipe(s) passing therethrough, and secured to said pipe(s) and to said case, and said containers being disposed around said pipe(s) between said two transverse partitions.

16/ A device according to claim 15, characterized in that said transverse partitions are spaced apart, preferably at regular intervals, along said longitudinal axis ZZ' by a distance of 50 m to 200 m.

17/ A device according to claim 15, characterized in that it includes at least one centralizing template, preferably a plurality of centralizing templates, located, preferably at regular intervals, between said two successive leaktight transverse partitions along said longitudinal axis ZZ', each centralizing template being constituted by a rigid part secured to said pipe(s) and presenting a shape which allows limited displacement of said case in contraction and in expansion in register with said centralizing template, said containers being disposed between two successive ones of said centralizing templates, where appropriate.

18/ A device according to claim 17, characterized in that said centralizing template is constituted by a rigid part, preferably having a cylindrical outside surface with a cross-section whose perimeter is set back relative to that of said leaktight partition, the centralizing template limiting deformation of said case by the case coming into mechanical abutment against said rigid part at at least two opposite points of the perimeter of the cross-section of said case, said displacement of the case in register with a said centralizing template representing variation of 0.1% to 10%, and preferably of

0.1% to 5%, of the distance between two opposite points of the perimeter of the cross-section of said case.

19/ A device according to claim 17, characterized in that said rigid piece constituting said centralizing template presents a portion of its outside surface that is set back sufficiently relative to the surface of the case, and/or presents perorations passing through it, so as to create a space allowing the material constituting said insulating covering to be transferred through said centralizing template.

20/ A device according to claim 16, characterized in that it has a plurality of said centralizing templates, and two successive centralizing templates are spaced apart along said longitudinal axis ZZ' of the case by a distance of 2 m to 5 m, with said containers being interposed between two successive ones of said centralizing templates.

21/ A device according to claim 16, characterized in that it has at least one, and preferably a plurality of shaping templates each constituted by a rigid structure secured to said pipe(s) with the pipe(s) passing therethrough, and secured at its periphery to said case, the shaping template(s) being disposed between two successive ones of said leaktight partitions, said shaping template having openings allowing the material constituting said main insulating material to pass through said shaping template.

22/ A device according to claim 21, characterized in that said open structure of said shaping template is constituted by a cylindrical part presenting a cross-section of perimeter that is inscribed in a geometrical figure identical to the geometrical figure defined by the

shape of the perimeter of the cross-section of said leaktight partition.

23/ A device according to claim 21, characterized in that it has a plurality of shaping templates disposed along said longitudinal axis ZZ' of the case, preferably at regular intervals, two successive shaping templates being preferably spaced apart by 20 m to 50 m.

24/ A device according to claim 1, characterized in that said case defines a perimeter presenting two axes of symmetry XX' and YY' that are perpendicular to each other and to said longitudinal axis ZZ'.

25/ A device according to claim 24, characterized in that said cross-section of the case is circular in shape.

26/ A device according to claim 24, characterized in that said cross-section of the case is oval in shape.

27/ A device according to claim 24, characterized in that said cross-section of the case is rectangular in shape, preferably with rounded corners.

28/ A device for thermally insulating a bundle of undersea pipes, the device being characterized in that it comprises a device according to claim 1 having at least two of said undersea pipes disposed in parallel.

29/ A device according to claim 28, characterized in that said leaktight partitions, said centralizing templates, and said shaping templates hold at least two of said undersea pipes at a fixed distance apart.

30/ A unit thermally insulating device suitable for building a device according to claim 1 by assembling said

unit thermally insulating devices end to end, the unit device being characterized in that it comprises:

· one or more unit undersea pipe elements replacing the undersea pipe(s); and

· an insulating covering, a said protective case, and a said insulating covering comprising at least one said container containing a said insulating phase-change material as defined in claims 1 to 14, each said unit element having at at least one of its ends or at both ends, a said leaktight partition, and preferably said centralizing templates and also preferably shaping templates as defined in claims 15 to 29 disposed between two successive leaktight partitions.

31/ A method of assembling a unit device according to claim 30, characterized in that it comprises the following steps:

a) where appropriate, positioning said unit pipe element(s) relative to said leaktight transverse partitions, said centralizing templates, and said shaping templates, then

b) installing said spacers on said unit pipe elements, or installing a said solid insulating material against the wall of said unit pipe element ; and

c) pressing said containers containing a said insulating phase-change material against said spacers or against a said solid insulating material ; and

d) inserting the assembly as obtained in step c) in a said outer case ; and

e) where appropriate, injecting a said main insulating material into the space between said containers and the outer case, and where appropriate into the space between said containers and the walls of said unit pipe element(s).

32/ A method according to claim 31, characterized in that said main insulating material is a mixture comprising

various components which are mixed together and then injected in the liquid state into the various compartments defined by said two successive leaktight partitions and said insulating material becomes transformed into a gel by at least one of its said components cross-linking.

33/ A method of thermally insulating at least one undersea pipe, the method being characterized in that unit thermally insulating devices according to claim 30 are made and then assembled together end to end.